

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

THE FIR TUSsock MOTH

(Observations in 1929)

by

R. E. Balch  
Agent

Forest Insect Field Station,  
Coeur d'Alene, Idaho,  
January 15, 1930.

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## HISTORY AND EXTENT OF OUTBREAKS

The fir tussock moth (Hemerocampa pseudotsugata McD.) was first reported at Chase, B. C., in 1918 where it was doing much damage to the Douglas fir. \*Blackmore then identified it as Hemerocampa vetusta gulosa Hy. Edw. In 1921, however, McDunnough \*\* reared some moths from the egg and described it as a new species on the basis of the color of the larval tufts and its feeding habits.

Since then local outbreaks have occurred at different points in the neighborhood of Vernon, Grand Forks, and Kettle River in B.C., but the insect was first recognized in the United States in 1927 when it was reported defoliating alpine fir on the Humbolt National Forest at Jarbidge, Nev. The following year it was noticed in one or two places on the Weiser, Idaho, and Boise National Forests, and at the Craters of the Moon National Monument.

In 1929 these areas were visited by the writer and found to be much more extensive than they had been reported. The whole of the Jarbidge canyon was infested and some of the trees were beginning to die. The greater part of the Douglas and grand fir on both sides of Meadows Valley, near McCall, Idaho, was being defoliated, and the same was found to be true of Round Valley and Price Valley, on the Weiser National Forest. Supervisor Raphael pointed out smaller areas in the neighborhood of Bear Creek and in the southern part of the forest near Blue Springs Creek. It seems likely that the infestation extends to a great deal of the fir stand in the Weiser which was not seen, but some forty square miles are known to be infested in this neighborhood.

At the same time epidemics had developed in northeastern Washington in the neighborhood of Northport and south of Grand Forks, B. C. Mr. Keen and Mr. Evenden visited the Northport area and found at least 10 square miles affected.

Although the fir tussock moth has been practically unknown until very recently and, because of the wingless condition of the female, is considered limited in its power to spread, it has been found within the past three years to have developed epidemics simultaneously over a number of considerable areas distributed from southern British Columbia to northern Nevada.

\* Blackmore, E.H. 1919. Report of Provincial Museum of Natural History, Victoria, B.C. for year 1918.

\*\* McDunnough, J. 1921. The Canadian Entomologist, Vol. 53, No. 3, p.53.

## NATURE OF INVESTIGATION

It was not possible to examine any of these infestations until 1929 and then only a limited amount of time was available. August 6, Roby Creek, near Boise, was visited with Mr. Stokes of the Boise National Forest. August 9 to 11 was spent in the neighborhood of New Meadows with Mr. Shellworth of the Boise-Payette Lumber Co. and with Mr. Raphael and other officers of the Weiser National Forest. The Jarbidge Canyon was examined August 13. On October 3 and 4 points on the Weiser were again examined.

On each of these occasions rough counts were made of parasites and material was collected for rearing and examination in the laboratory. In November a collection of egg masses was sent in by Mr. Evenden from the Northport area.

As the writer does not expect to be able to continue this work the very incomplete results of this preliminary investigation are given in considerable detail for the assistance of anyone who may carry on with it. Much of it is theory based on brief examinations, but it is thought that a general discussion of the insect may be of interest owing to its comparatively recent appearance as an enemy of forests. It is intended also for the information of the timber owners and forest officers concerned, and attempts to answer, in so far as is possible at this time, most of the questions they have asked.

## DESCRIPTION OF THE INSECT AND ITS LIFE HISTORY

### Larval Stages

Although Blackmore says there are two broods it seems unlikely that there are more than one. Hopping is reported by Keen \*\*\* as saying that the eggs hatch in the fall and the young larvae overwinter in the cocoons, but no evidence has been found to confirm this and there is no question that the majority of the eggs do not hatch until spring.

Eggs brought into the laboratory November 20 and kept at room temperature hatched December 18. It seems probable that in the field they do not hatch until the buds begin to open and the young larvae do their first feeding on the young growing needles. In the laboratory, however, these first stage larvae have, of necessity, eaten the 1929 foliage and although many have died a few have moulted twice.

\*\*\* Keen, F.P. 1929. The Tussock Moth Menace. Timberman, September 1929.



The First Instar: At hatching the larva is slightly over 2 mm. long with a head capsule .53 mm. wide. The head is brown with whitish clypeus and mouth-parts, except the labrum. The body is dirty grey, tinged with red, but increases in size and becomes greenish with feeding. Large dark brown "plates" are arranged on the body segments (as Figure 1), and correspond to the tubercles of later stages. From them arise long hairs with small barbs on them. Many of these are as long as the body itself and probably serve as protection and as an aid to dissemination by the wind. The caterpillar, when disturbed, curls up, forming a ball surrounded by hairs.

Each proleg is provided with four large hooks, or crotchets, two anterior and two posterior.

These small caterpillars are very active and are great travellers. On a smooth surface they are capable of crawling a foot in two minutes and probably they go a long way in search of suitable food. Their tendency is to travel upwards and they no doubt concentrate in the top of the crown. When jarred from a twig they drop on a long thread of silk attached to the twig. If they do not reach a lower limb and are given an opportunity they will climb back up the thread, gathering the silk in a ball between the prothoracic legs by means of the mouth. In a wind, however, they are likely to be separated from the tree. The hairs on the body, together with a long silk thread, offer a great deal of resistance to the wind. Rough experiments show that first-stage larvae could probably be carried considerable distances when the wind velocity is above 10 miles per hour. In view of their habit of upward migration the chances of dissemination by wind, especially from the tops of ridges, must be considerable, and it must be chiefly at this stage that the insect is spread.

The Second Instar: The first moult took place in the laboratory about 10 days after hatching. This may have been delayed by unsatisfactory food. The head capsule of this instar is about .78 mm. and the length of the larva about 5 mm. The tubercles (or verrucae) are smaller, in relation to the body, and paler. From two large warts on the prothorax arise short black plumed hairs. Similar tufts of plumed hairs appear on the first, second, and eighth abdominal segments. Two round yellow glands (osmeteria) protrude from the dorsal side of segments VI and VII. Segment V is shaded dorsally with yellow.

The Third Instar: Third instar larvae appeared 8 days after the second. Head capsule 1.25 mms. Length about 9 cms. The tufts of black hairs are somewhat larger. The head is paler; verrucae also paler except dorsal verrucae on abdominal segments I-IV which are almost black. The body is greyish white with the dark brown shading more distinct. Segment V is completely yellow dorsally. A few white feathered hairs arise on segments III and IV. The glands are bright red with an orange tinge.

Final Instar: There are five larval instars according to McDunnough, but the fourth has not yet been observed by the writer. According to Dyar's law the ratio of increase in the width of the head capsules of the instars is constant. From the first three measurements this constant ratio seems to be about 1.5. Applying this to the measurement of 1.25 mms. for the third instar we get 2.8 mms. for the fifth. The full-grown larvae examined from Weiser measured from 2.9 to 3.1 mms. This larger size may be due to the fact that the larvae bred in the laboratory have been fed entirely on old foliage.

The final instar (Fig. 2) is reached around the end of July. The head is dark brown with a whitish clypeus. It is 2.9 to 3.1 mm. wide. The body is about 3.0 cms. long. There are two color phases: one with the ground color greyish, the other light fawn. The greyish type is striped dorsally and laterally with black, with a brown mid-dorsal line. The fawn type has a broad brown dorsal stripe becoming yellow around the verrucae, and is marked laterally by a vague brown stripe with yellow areas between the segments. These fawn larvae seem somewhat larger than the greyish larvae and it is thought that they may be the females, but this has not been proved. The verrucae and glands of both are bright red and bear numerous yellow and black barbed hairs. Two lateral protuberant warts on the prothorax carry long, black pencil tufts of plumed hairs, and a corresponding one arises dorsally on the eighth segment of the abdomen. Dense tufts of barbed hairs, suggesting a toothbrush, cover the greater part of the dorsal area of abdominal segments I, II, III, and IV. These hairs are pale at the base and tipped with brown, more darkly so on the greyish phase.

Larval Habits: Larvae of the first three instars feed almost entirely on the under side of the needles when on old foliage. The third instar frequently attacks the upper side but does not make such good progress there. In feeding the mandibles are forced through the epidermis, generally in the region of the stomata. The caterpillar lies along the needle and twists its head so as to get one mandible above and the other below the epidermis. After this is chewed the mesophyll is rapidly eaten down as far as the fibro-vascular bundles. Thus less than half of the leaf tissue is consumed and the larva progresses rapidly along the needle. A third stage larva was observed to eat out the lower part of a 2 cm. needle in a little over half an hour. Feeding is confined roughly to the area bounded by the outer limits of the stomatal rows. Intentionally or unintentionally the resin ducts are left. Such partial feeding almost immediately destroys the leaf as a functioning organ, and the damage done by the smaller larvae is large in comparison to their size.

The last two stages of the larva feed on both old and new foliage and consume the whole of the leaf. Sometimes the needle is chewed through part way from the tip, often it is eaten from the tip backwards to the base (Fig. 2 #7). With the growth of the caterpillars defoliation

progresses very rapidly during the latter part of July and quite often an epidemic may go unnoticed until the larvae have almost finished feeding. At this time the loss of foliage uncovers the twigs and gives the trees a distinct brown cast, distinguishable from a considerable distance. The caterpillars also become much more noticeable. For these reasons reports of new outbreaks are not generally received until late July.

Prior to moulting the larvae attach themselves to some surface by a number of silk threads and remain quiet for a day or more. The posterior half of the cast skin is left attached by the silk as the new instar emerges.

In travelling from twig to twig silken strands are often dropped from one point to another. These are added to by a number of larvae following the same direction and adding more silk, until a sort of bridge is formed along which the larvae pass from twig to twig. This causes the silken tent-like appearance in the tops of infested trees which has been noticed by a number of forest officers when the sun is behind the trees.

The Cocoon: About the first of August (these dates are approximate for the Weiser National Forest and will vary somewhat with exposure, altitude, and latitude) the full-grown larvae commence to spin cocoons. These are attached to all parts of the tree: to the under side of the foliage -- if any be left -- to the twigs, limbs, trunks, and underbrush. Many are spun among the lichen (Alectoria fremontii?) which hangs from the trees. They frequently collect in large groups beneath the bases of limbs, sometimes one upon the other as many as six deep. In this case it has been observed that the adults are unable to emerge from the lower layers.

The cocoon is spindle-shaped, made of a thin but tough texture from silk and hairs from the insect's body woven together. The hairs become entangled in the silk, partly owing to the barbs, during the process of weaving. It is greyish brown and often consists of two layers, an inner and an outer. That of the female is about 2.6 mms. long, of the male 2.0 mm. (Fig. 2 #7).

The larva, after it has covered itself with this protection, is almost devoid of hairs, except for the remains of the four dorsal tufts. It then enters the prepupal stage, becoming shorter, somewhat thicker, with a tendency to taper posteriorly.

The Pupa: The caterpillar, if parasitized, generally dies at this stage and nothing is left but the dried skin containing the parasitic larva or larvae (Fig. 11). Normal caterpillars, however, moult and become pupae after a brief period of quiescence.



The pupae of the two sexes are quite distinct (Fig. 3); the female having a much larger abdomen and indications of her smaller antennae. They are light shiny brown at first, becoming dark as they mature, and are covered with a straw-colored pubescence of long unbarbed hairs. The average length of the male is about 12.4 mm., of the female 17.9 mm. The pupa is attached to the inside of the cocoon by the hooks of the cremaster and this aids emergence of the adult.

The Adults: After a period of about ten days (a rough estimate for want of exact observations) the moths emerge by splitting the pupal case dorsally down the centre of the thorax and along the sutures bordering the wings and antennae. Unparasitized cases can thus be distinguished from those which produced parasites as the latter have the head end irregularly chewed or broken off (Fig. 2 #4).

The female moth is wingless, having but two short rudimentary stumps. Her body is covered with a dense coat of hairs which are grey to fawn toward the base and black at the tip. The arrangement of these on the last three abdominal segments causes a heavily barred appearance. (Fig. 2 #3). The head, thorax, legs, and first four segments of the abdomen are greyish tinged with fawn. There is a fine black centro-dorsal line. The antennae are about 2.5 mm. long and not noticeably pectinate. The abdomen is packed with eggs, as many as 122 having been taken from one female. These eggs are full formed before emergence.

The male has well developed wings. The primaries are dark, greyish chocolate brown dorsally, with two irregular dark bands (Fig. 2 #5). White scales are scattered more or less evenly over the wing, especially around the base and along the apical margin. The secondaries and the under side of the primaries are a lighter, uniform rusty brown with darker marginal shading. (Fig. 2 #6).

Mating and oviposition take place shortly after emergence. The female is very inactive and almost invariably lays her eggs on top of her own cocoon. (Fig. 2 #1). Of 45 egg masses counted the average number was 136 eggs. These varied from 52 to 178 in a mass, and it is possible some of the larger masses contained eggs from more than one female.

#### The Eggs

The eggs are spherical -- not hemispherical as in McDunnough's description, but slightly flattened on one side (Fig. 4). This flattened area is marked with a faint hexagonal sculpturing -- corresponding possibly to the follicular cells -- and in the centre is a dark spot, the micropylar area.

The outer shell, or chorion, is opaque white, but becomes transparent on treating with xylol. Within this is a thin vitelline membrane, the amnion. In parasitized eggs this becomes black. Within the amnion is a red protoplasmic reticulum which surrounds and pervades the yolk in a hexagonal pattern. The yolk is greenish yellow and consists mainly of fat globules.

The eggs are laid in a mass with the micropylar area outward. This seems to be the cephalic pole and if it corresponds with that of the adult, as in most insects, one would expect them to be laid in this way. They are covered with a frothy, transparent, gelatinous substance, within which are embedded the hairs from the abdomen of the female.

On emerging from the egg the young larva breaks the shell in such a way that the top half is entirely removed. Shells with small neat round holes are those from which parasites have emerged. (Fig. 5).

#### Poison Hairs

Hopping (Keen 1929) tells of the hairs of the caterpillars causing eczema in British Columbia. Two relatives, the white-marked tussock moth (*H. leucostigma*) and the brown-tail moth (*Euproctis chrysorrhoea*), have been reported as causing a serious irritation of the skin. It has been proved that the brown tail has poisonous hairs, but there is some difference of opinion about the white-marked tussock moth. Gilmer,\* however, claims to have discovered poison glands at the base of many of the hairs, particularly in the four dorsal tussocks.

The writer, when working among heavily infested trees in hot weather, suffered an irritation of the skin where exposed to the hairs from the caterpillars and cocoons. This lasted for about two days, but did not produce any serious urticaria or eczema. Superficial microscopic examination of the hairs showed nothing corresponding to the poison hairs of the brown-tail and the mechanical effect of the barbs which are found in different sizes and shapes on practically all of the hairs would seem to have been sufficient cause. There might possibly be some form of protein poisoning in the cases of certain people, or there may be a poisonous element within the hairs.

### THE DAMAGE

#### Nature of Feeding

Although actual feeding has not been observed in the field, laboratory observations and examination of the defoliated trees suggest that the first one or two instars feed chiefly on the new growth in the

\*Gilmer, P.M. A Comparative Study of the Poison Apparatus of Certain Lepidopterous Larvae. #198, Jour. of Minn. Agr. Exp. Sta.

upper part of the crown. In this way many of the buds are killed and the leader is always the first part of the tree to die. Even the first instar, however, is capable of feeding on the previous year's needles and as the larvae develop all the foliage of a well infested tree is devoured. First the under side only is scooped out, later the whole needle is consumed and many of the new shoots are chewed into and killed.

The upper third of the crown, owing apparently to the negative geotropism of the insect, is always defoliated first and most completely. Later the larvae drop to the lower foliage and many to the ground where they may feed to some extent on the underbrush. In a heavily infested area the supply of foliage on a tree is often insufficient to bring its population to maturity and caterpillars will be found in great numbers on the ground travelling rapidly. They climb the first tree they reach regardless of whether it has already been defoliated. In this way, at the height of an epidemic many are starved. Also the infestation is spread out somewhat by this power of travel of the last two stages of the larva. Even over rough ground a full-grown caterpillar can travel from one to one and a half feet per minute. This method of spread does not compare, however, with the importance of windborne larvae of the first instar.

#### Host Preferences

The fir tussock moth is capable of feeding on many different plants, but as far as we know has a very decided preference for species of true firs and Douglas fir, and can only reach epidemic proportions where such preferred food is plentiful.

Three species have been found capable of fostering an epidemic. At Jarbidge alpine fir (Abies lasiocarpa), which occurred pure and mixed with limber pine, was the species attacked. At Boise the damage was in pure Douglas fir (Pseudotsuga taxifolia). At Weiser both Douglas fir and grand fir (Abies grandis) were attacked in mixture, but grand fir was distinctly the preferred host (Fig. 6). Nowhere was the moth found in large numbers except where grand fir formed a good proportion of the stand. Complete defoliation had taken place where the stand was pure grand fir, but as Douglas fir increased in numbers the damage decreased, and while this latter species was often completely defoliated it was generally less severely stripped than the true fir. At Northport, according to a letter from Mr. Hopping and reports from Mr. Evenden and Mr. Keen, exactly the reverse condition obtains. There and in Canada the preferred host is Douglas fir and grand fir is attacked only when mixed with the preferred species.



The caterpillars will feed on many different conifers when these are mixed with the preferred host. Apparently the young stages when forced to feed on other conifers than fir suffer considerable mortality, but a percentage are able to pull through. The last two stages seem capable of completing their development satisfactorily on a new host. Feeding has been noticed on yellow pine (P. ponderosa), hemlock (T. heterophylla) and larch (L. occidentalis). Occasionally yellow pine was almost entirely defoliated when closely surrounded by grand fir (Fig. 6), but otherwise feeding was extremely light on these other conifers.

It seems that with this insect, as with the spruce budworm, different localities may produce different biological races with different food preferences. Whether these are distinct varieties, or whether such preferences can be altered in a few generations has not been determined. However, at one point on the Weiser the larvae were found to have defoliated the shrub Pachystima myrsintea quite thoroughly even though the fir trees above still bore a good deal of uneaten foliage. There was an apparent preference for the shrub over the fir, while not much more than ten miles away at another centre of infestation the fir was completely defoliated and the shrub but little fed on. This would seem to suggest that a change in host preference may take place within a few generations.

A male from Jarbidge sent to Washington was determined by Mr. Heinrich as a variety of H. pseudotsugata McD. The insects used for the description in this report were from the Weiser infestation and seem also to be a variety of the species described from Canada by McDunnough.

#### Effect on the Stand and Commercial Importance

The damage from defoliation depends on the number of trees killed, the defects caused in those which survive, the effect on the composition of the stand, and the value of the species concerned. To estimate this a long period of observation is needed. The present condition is described.

It is known the insect was noticeably abundant at Jarbidge in 1927, and on the Weiser in 1928. It is probable that both of these epidemics were well under way in 1927 but only covered part of the area now infested. On the old infested part at Jarbidge fifty per cent of the trees were dead or dying in August, 1929, and a good many more may die in the next few years. The merchantable trees were then being cut as a salvage measure.

Two wood borers were busy ovipositing on the dead and dying trees and would do a good deal of damage if the timber was not used. One was Monochamus oregonensis, a large blackish beetle with long antennae; the other Sirex juvencus race cyaneus, a large horntail with a dark metallic blue body and reddish legs (Fig. 5). Both bore large galleries in the wood.

In the Weiser area it was more difficult to date the epidemic as it had been preceded apparently by a milder outbreak of the spruce budworm (Cacoecia fumiferana). The reproduction showed a great many crooks which seemed to have been caused by the death of the leaders between three and five years ago. In a good many cases the lateral replacing the leader had again been killed (Fig. 8). Since one of the first injuries caused by defoliating caterpillars is the death of the leader it seems that some kind of defoliation has been going on for a number of years. At the same time 1929 was the first year of complete, more or less general, defoliation (Fig. 7).

In August the trees that had been completely stripped showed moist, normally-colored cambium and while most of the leaders had been killed and many of the buds in the upper part of the crown were destroyed the majority of the buds seemed healthy. Only a few of the smaller trees were obviously dying. By October, however, many of these buds had withered and quite a few of the trees had a faint discoloration of the cambium. It seems likely that perhaps the majority of these completely defoliated fir will die. A good deal of foliage may be put out next spring. If natural factors of control do not stamp out the epidemic the caterpillars will soon destroy this. If, however, the insect is scarce next year many of the trees may pull through, although there will probably be some delayed mortality during the year or two following.

From reports by Mr. Evenden somewhat similar conditions seem to obtain at Northport.

Apart from mortality, loss of increment, and defect are also caused by defoliation. Most of the trees which survive will have the upper two or three feet of the crown killed and a great many twigs and buds on the outer edge of the lower part of the crown. The result will be crooks and probably decay at the point of crook. This applies to reproduction as well as large trees (Fig. 9). Such trees would be better dead. The added fire hazard resulting from the dead trees will be likely to bring this about eventually.

It is difficult to say whether there will be any effect on the species composition of the stand. In the Weiser district the infestation is in white fir type, which occurs on the moister slopes and is interrupted and bordered on the lower elevations by yellow pine. Destruction of the

fir might admit the less tolerant yellow pine reproduction. However, there will be enough fir left on the edge of the fir type in most cases to seed in the destroyed area and the pine will probably be unable to compete on what is essentially a fir site. On the other hand preference of the insect for the grand fir may give some advantage to the Douglas fir and increase its occurrence in the stand.

In the Jarbidge Canyon alpine fir and limber pine (P. flexilis), together with aspen (P. tremuloides) form practically the whole of the forest. Owing to a severe epidemic of Dendroctonus monticolae most of the pine has been cut or killed. Now that the fir is attacked it is difficult to say what will be the ultimate effect of these two insect epidemics.

All three of the species attacked are of wide distribution throughout the mountain areas of the West. Douglas fir is considered the most important commercially. Grand fir, owing to its susceptibility to rot as it matures, is not generally considered a valuable tree among lumbermen. The Forest Service, however, attaches more importance to it as a tree of the future, owing to its rapid growth. On a short rotation, provided it was protected from defoliators, it would be reasonably free from rot. Alpine fir occurs largely in rather inaccessible regions and is seldom of much commercial value except for watershed protection. At Jarbidge, however, it is of considerable value. The mining town of Jarbidge is very isolated and depends on the forest within the canyon for its timber and fuel. The only species which grow are alpine fir, limber pine, aspen and mountain mahogany. The pine has been largely destroyed by the mountain pine beetle. The supply of timber and fuel is very inadequate for local demands.



## CONTROL

### Natural Control

It seems that the general course of an outbreak of a defoliating insect is somewhat as follows: During a year, or more probably a number of years, of favorable environmental conditions, the insect increases in numbers in a certain area until the damage to the host trees becomes noticeable and an epidemic is recognized by any observant person. For a year or two the numbers of the insect increase further and the area of defoliation enlarges until a considerable area is completely stripped and the supply of food is insufficient to support the population of insects. Meanwhile parasites and predators have increased in numbers, following the increase of their insect host. At this time the defoliator suffers considerable mortality from starvation, is weakened and subject to disease, and parasites and predators are sufficiently numerous to attack a very large percentage of the survivors. In other words, the factors of natural control "catch up" with the species which has temporarily broken loose from their influence.

Conditions of course frequently modify this sequence. Unfavorable weather at a vulnerable stage of the insects' life history may nip an incipient epidemic in the bud. Efficient parasites or predators may not be present and the epidemic may continue for some time if its powers of spread are adequate. To prophesy the future of an epidemic is more than risky.

However, observations on the Weiser National Forest suggest that the peak of the epidemic has been reached. In early August large numbers of caterpillars were found swarming over areas where practically all the foliage had been destroyed and the ground beneath the trees was strewn with dead larvae. A number were found to have died clinging to the twigs in a characteristic attitude with the head and posterior end lifted up from the twig. Some of these were flabby and some as though mummified and it is possible they had been attacked by disease.

Counts of pupae were made in October at three points, two on the west and one on the east side of the Meadows valley. The results at each point were roughly similar and they are summarized as follows:

	<u>Total</u>	<u>Per Cent</u>
Cocoons examined	300	100.0
With egg masses (females emerged)	19	6.3
Male moths emerged	15	5.0
Parasite larvae overwintering in cocoon	18	6.0
Parasites emerged (or died)	236	78.7
Pupae died unparasitized	12	4.0

Although the count is small the figures give some idea of the conditions at centers of infestation in the Meadows Valley. Eleven and three-tenths per cent of the pupae produced adults, 84.7 per cent were parasitized, 4 per cent died from some undetermined cause. It is, of course, possible that even this degree of parasitism is insufficient to bring about a considerable reduction of the epidemic, but combined with egg parasitism, starvation, etc., it should have an important effect.

The most important parasite here was a large fly (probably Tachinidae, Figs. 10 and 11), not yet determined. A smaller dipterous larva and a hymenopterous larva occurred in fewer numbers. These occur from one to five in a pupa and sometimes two species in one host, but the adults have not yet been reared. There was also a small gregarious chalcid of little importance -- awaiting determination. In addition a large number of eggs were parasitized by Trichogramma minuta (Fig. 12) and a few by species of Telenomus (Fig. 4).

A rather high degree of parasitism was observed also at Jarbidge and near Boise. A large ichneumon (probably Theronia sp., Figs. 13 and 14) has been bred from material from Northport together with considerable numbers of Trichogramma. Most of these parasites have not yet been determined but a few notes and figures are given at the back of the report.

A certain amount of mortality was found to result from the overcrowding of the cocoons. Masses of over fifty cocoons were gathered beneath the bases of limbs several layers deep. The pupae at the bottom produced adults but these were unable to emerge through the overlying cocoons. In one mass of 112 cocoons were found 18 moths which had failed to emerge after coming out of the pupal case.

No predators have been observed. Birds were not of noticeable importance. On one tree swarming with caterpillars a good deal of bird excrement was noticed containing a large amount of insect remains. Analysis showed that this consisted largely of pieces of miscellaneous beetles and although one tussock larval head capsule was found, together with a considerable number of hairs, the caterpillars had evidently formed only a small portion of the birds' diet. This proves nothing, but suggests that in the presence of an epidemic birds do not concentrate on the abundant larvae but continue a varied diet. The tussock larvae, of course, may be unpalatable owing to their heavy coat of barbed hairs -- some possibly poisonous.

#### Introduction of a Predator

Dr. Craighead has suggested that a large predacious ground beetle (Calosoma sychophanta) may possibly be obtained from the Gipsy Moth Laboratory in the East and liberated in sufficiently large numbers to establish colonies that would aid in control. This beetle was introduced from Europe to feed on the gipsy and brown tail moths -- both of the same

family as the fir tussock moth -- and has proved of considerable value. It climbs the trees in search of its prey and both adults and larvae are predacious.

This experiment seems well worth trying. If the epidemic is considerably reduced next year the beetles will not have the opportunity of rapidly increasing their numbers and becoming effective in control that they will have if the epidemic continues. However, in any case, their establishment in the region is desirable from the point of view of the future. If the climate is suitable -- and it does not differ seriously from New England where the beetles thrive -- they may become generally established and act as a check during future endemic and epidemic periods.

It would be desirable to liberate colonies at Jarbridge, on the Weiser, and at Northport. If this is not possible the two latter regions would be more accessible for making subsequent observations. A point where the caterpillars are numerous should be chosen and it should be carefully marked. On the Weiser an area should be selected where there is a considerable stretch of grand fir, at Northport the Douglas fir type must be chosen.

#### Artificial Control

There are three means by which the insects may be artificially destroyed: by fire, starvation, or poison. The effective and economical use of these methods depends on the discovery of an epidemic in its early stages. If the centre and extent of a developing infestation can be determined before too large an area has been affected it may be possible to apply control measures to this comparatively small area. When, however, as is generally the case under present conditions of extensive management, infestations are not recognized until they have covered a lot of ground and perhaps the epidemic is at its peak, control measures are out of the question. For one thing they are too costly; for another, if the epidemic has reached its peak parasites are numerous and control may destroy them as well as the caterpillars; for another the greater part of the damage has already been done.

A better knowledge of the important parasites and their habits, and of the powers of spread which the tussock moth possesses, is necessary before this question can be adequately discussed. We need to have some measure of the status of an outbreak and to know something of its probable extension. This is not easily arrived at but it seems that the present epidemics have reached a stage where it is wisest to leave them to the factors of natural control. It would do more harm than good if artificial methods of control were adopted which killed the parasites as well as the caterpillars. This point can only be settled however by further observations next year.



Destruction by fire would mean burning over the infested area between September and May. Both the underbrush and crowns would have to be reached in order to destroy all the egg masses. This, of course, would destroy the trees as well as the parasites and could only be contemplated where the area was small and the neighboring stands of sufficient value to warrant protection. In the case of valuable trees it might be possible to collect the egg masses by hand and burn them, but this would entail a lot of labor. They are easy to see but some of them are high in the crown.

Destruction by starvation would be accomplished by clear-cutting the infested area before the eggs hatched. This would call for the cutting of reproduction as well as larger trees. Where underbrush is thick it may be sufficient to permit larval development in the absence of the preferred host. The effect of other coniferous hosts is uncertain and some experimentation is necessary on this question, but there is the possibility that if any trees are left the small hairy caterpillars may climb them and be carried outside the control area by wind. Logging and broadcast burning would be the most certain method of destruction.

Destruction by poison is an expensive and difficult method against forest insects, owing to the low value of the crop per acre and to the roughness of the ground which interferes with the handling of equipment. In Germany the application of poisonous dusts from aeroplanes is being practiced on forest land, commercially. In Canada a good deal of experimental work has been done and it has been proved possible to control certain forest defoliators by this method. It is, however, expensive and calls for some considerable preparation and training on the part of the pilot, as well as being dependent on satisfactory weather. Under present western conditions it does not seem advisable to attempt this method, but it should be borne in mind as a possible means of control in the future. When the timber threatened becomes more valuable and is more intensively managed, and when the technique of aeroplane dusting has been improved, it should be possible to recognize outbreaks in time to control them economically by poison from the air.

The poison best adapted for the fir tussock moth is arsenate of lime. This is the cheapest and apparently most effective dust. It should be applied some time when the caterpillars are small -- the best time needs to be worked out by experiment. In the case of valuable trees which can be reached from a road a power sprayer may be used -- such as is employed against the gipsy moth.

The wingless condition of the female moth suggests that the insect is not capable of rapid dissemination and this fact would be a great assistance in control measures. The wide distribution of the insect in 1929, however, also suggests that it is quite capable of spreading, and at a fairly rapid rate. There are a number of possible means by which

spreading might be brought about. The mature larvae crawl from tree to tree, they may fall on sheep, pack trains, etc., which would carry them some distance, and it is barely possible that fertilized females may be swallowed by birds and the eggs pass through uninjured. None of these means, however, seem likely to be very effective. The hairy condition of the first instar (Fig. 1), coupled with its habit of travelling toward the top of a tree and dropping on a silk thread, seem to offer the best solution to the problem. There is no doubt that even moderately strong winds are capable of carrying them considerable distances.

### SUMMARY

The fir tussock moth has during the past three years become epidemic at a number of points in Washington, Idaho, and Nevada.

It has completely defoliated stands of alpine fir, grand fir, and Douglas fir. Other species are but slightly affected. Preference for these hosts varies in different areas.

Many of the trees and much of the reproduction have been killed or will die. Others will have dead tops and will probably decay.

The insect and its habits are described. The caterpillars commence feeding as the new growth comes out. They are full grown by the end of July. The moths emerge and lay eggs during the latter part of August. The winter is spent in the egg stage.

The female is wingless. The spread of an infestation must take place during the larval stages. The young caterpillars can be carried considerable distances by the wind.

In 1929 a good deal of mortality resulted from starvation owing to the large numbers of caterpillars. Parasites of larvae and eggs were very numerous. It seems likely that the peak of the epidemic has been reached.

Artificial control would call for the burning over of the whole infested area. Winter clear-cutting of all the fir might serve the purpose. Dusting or spraying with calcium arsenate would be effective if practicable. Experimentation is needed.

None of these methods are recommended in the present epidemic. It seems best to rely on natural factors of control. The introduction of a predacious beetle from the East is contemplated.

## PARASITES

The following incomplete notes on parasites are recorded for future reference. Determinations have not yet been received from Washington and Hopkins numbers are used except where determinations have been made by the writer, tentatively.

### Egg Parasites

#### Trichogramma minuta Riley (18690 and 18796)

This cosmopolitan parasite is common at Jarbidge, Weiser and Northport. Some material from Northport had close to 20 per cent of the eggs parasitized by this species.

It is gregarious, from 4 to 11 in an egg. When there is a large number they seem smaller in size. They are apparently capable of developing in fertilized and unfertilized eggs. One egg was found in which two Trichogramma had developed to adult form together with the tussock moth embryo. The latter was almost fully developed, with dark brown head and long barbed hairs, but had died before hatching. Apparently both embryo and parasites had fed independently on the yolk.

The larva is ovoid in shape with a transparent body wall and no discernible segments. There are two slender brownish processes -- probably atrophied mandibles -- at one end. The body contains a large number of white irregularly spherical "fat bodies".

The adults are minute, yellowish green, chalcid flies with red eyes. The male is shaded with black. See Fig. 12.

Oviposition takes place in the fall and the adults emerge in the spring about the same time as the tussock moth eggs hatch. The emergence hole is round and neatly chewed out by the mandibles of the adult, about one-fourth the diameter of the egg. (Fig. 4). In parasitized eggs the amnion turns black.

When spruce budworm eggs are the host Trichogramma emerges in the fall.

#### Telenomus sp. (18683)

This somewhat larger blackish chalcid occurred at Weiser in smaller numbers, and apparently not more than one to an egg. The emergence hole has about half the diameter of the egg. (Fig. 4).

This parasite was found within the eggs of a tussock moth pupa which had died before transforming. The eggs within the abdomen of the pupa were fully formed and half of them had been parasitized. The skin of the dead pupa had been ruptured and it is thought that a Dermestid (18701) which commonly feeds among the old cocoons may have broken it sufficiently to allow the entrance of the adult parasite.

See also 18698 and 18797.

### Larval Parasites

#### Tachinidae?

The most important parasite at Weiser and Jarbidge was on a fly, the adult of which has not yet been reared. The larva is white and about 10 mm. long. The puparium is dark red-brown, about 9 mm. long and 3.7 mm. wide (See Fig. 10).

In most cases this parasite allows the larva to spin its cocoon and reach the prepupal stage when it shrivels up and forms a fairly hard casing for the parasite (Fig. 11). Sometimes the pupal stage is reached. The parasite larva is capable of emerging from this and will sometimes pupate in the cocoon, but probably more often drops to the ground. The winter is apparently spent in the larval or pupal stage.

It is not known whether more than one larva of this species develop within each host, but from 1 to 5 dipterous larvae have been commonly found together. There is, however, at least one other species of diptera concerned, which has not been distinguished in the larval stage. It has a distinct puparium, being somewhat smaller with two "scalloped", shell-like protuberances at the anterior end in contrast to the smooth flat discs on the former species (Fig. 10). Also the anal end is invaginated and has a distinct "hole".

An interesting observation was made of a tussock moth "larva" which had been finally killed by three of these dipterous parasites half way between the prepupal and pupal stages. The abdomen was pupal with a fully formed cremaster. The thorax and head were larval with the legs still intact.

#### Ichneumonidae

Ephialtes sanguineipes (Cress.) . Adults with body 13 cms. long, all black except reddish-brown legs. Emerged in laboratory September 10 from material collected at Jarbidge.

Conoblasta fumiferanae Vier. Pupae within thin parchment-like cocoons within tussock moth pupal cases.



Theronia atalantae var. fulvescens (Cresson)? According to material collected at Northport this parasite (18709) is the most important in the Washington outbreak and is quite numerous. The larvae occurred solitary and of nine examined all were inside dead female pupae. Some almost filled the pupal case, others were smaller, lying surrounded by the almost fully formed eggs with their heads within the thorax of the host.

Brought into the laboratory November 21 pupation commenced in a few days and adults emerged December 1. With each cast pupal skin was found a long convoluted soft white intestine-like mass -- probably the meconium -- and a harder capsule-like body, somewhat sausage-shaped, composed of a greenish substance within a membrane. This was 2 mm. long and .6 mm. wide.

The larvae (Fig. 13) are white, with a transparent skin through which the tracheae and fat bodies are clearly seen. The alimentary canal shows black. The spiracles are round and surrounded by a brown ring. The head capsule is white except for two purplish-brown horn-like markings (Fig. 13 ~~14~~).

The adult is solid amber yellow with dark eyes and antennae (Fig. 14).

This is a common parasite on Lepidoptera in the West.

#### Chalcidoidea

#18795 - Pteromalidae (not determinable). This small chalcid was reared from a group of Braconid-like cocoons within the cocoon of the tussock moth. No braconids were found but the chalcid larvae were within a brown dried larval skin within the papyraceous cocoons. About 30 of these cocoons were built close together within a silken fuzz, the whole within the tussock cocoon together with the remains of the larva. There seems no question that the chalcid is a hyperparasite.

See also Hopk. #18716 (Hyposoter pallipes (Prov.))

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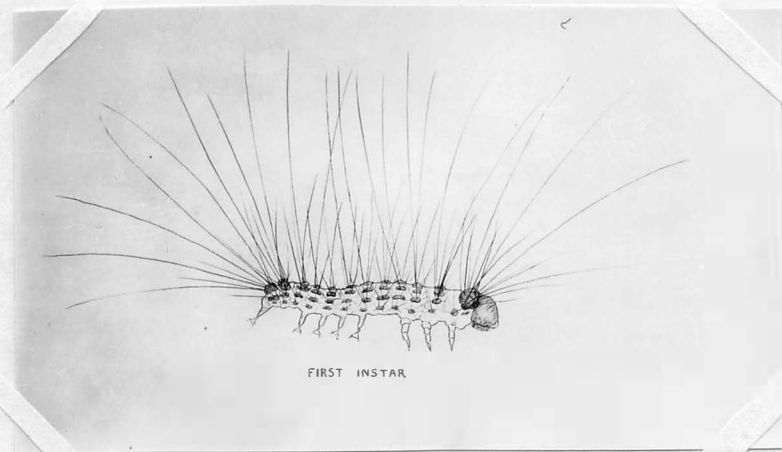
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#### Chalcididae

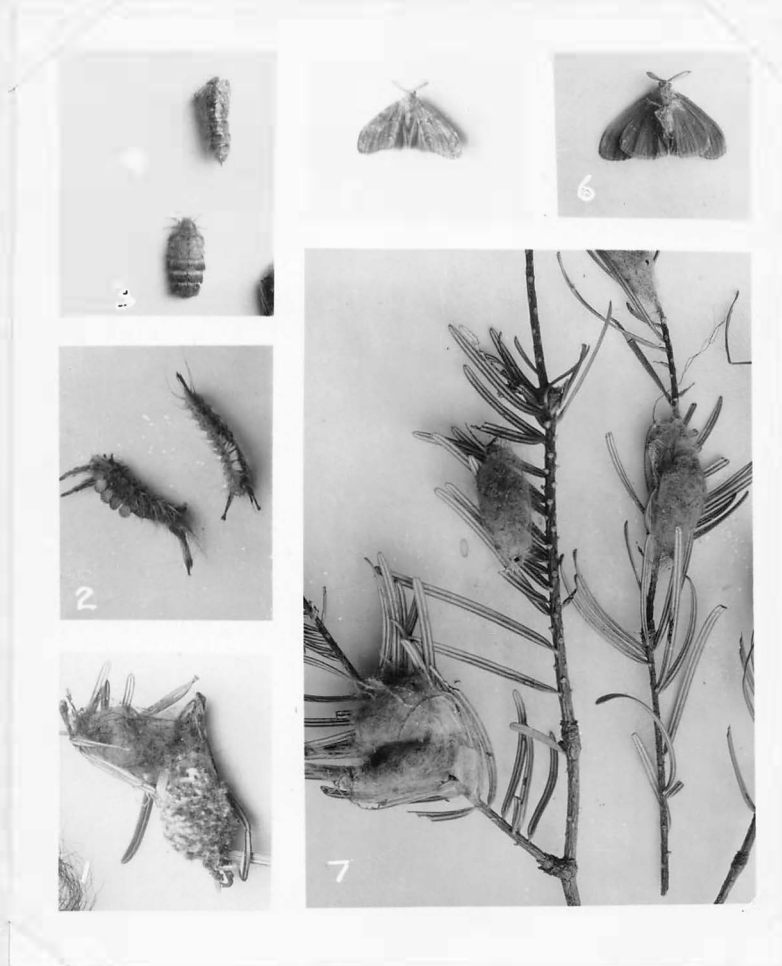
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See also Hopk. #18716 (Hypocryptus pallipes (Prov.))



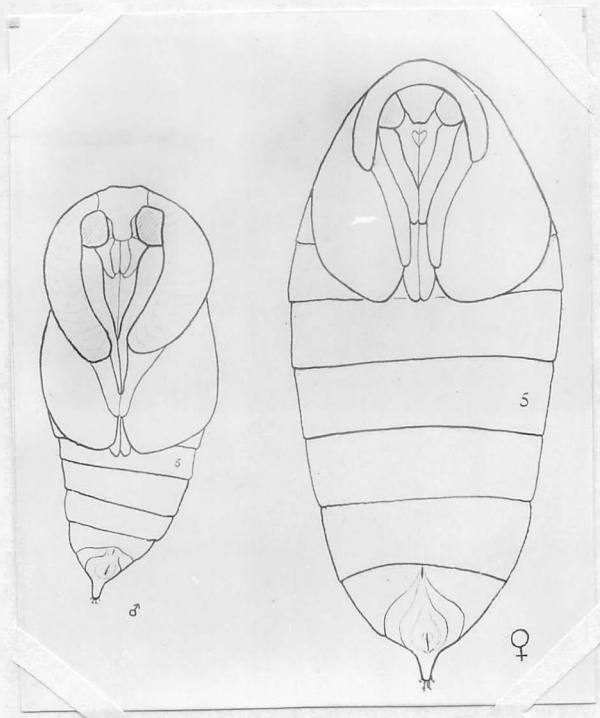
First Instar

Fig. 1



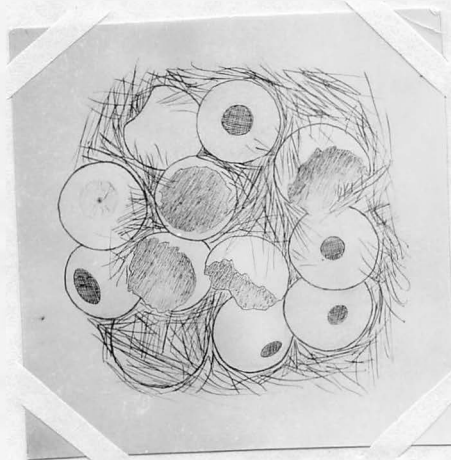
1. Egg mass
2. Fifth instar
3. Adult female
4. Pupal case  
(parasitized)
5. Adult male (dorsal)
6. Adult male (ventral)
7. Cocoons

Fig. 2



Male and female pupae

Fig. 3



Part of an egg mass showing hatched and unhatched eggs, and emergence holes of Trichogramma and Telenomus parasites.

Fig. 4



Monoctonus oregonensis

Sirex juvenis cyaneus

Fig. 5





Defoliated trees at Weiser,  
showing Douglas fir less  
severely defoliated than  
grand fir. In center a  
yellow pine surrounded by  
grand fir has been almost  
stripped.

Fig. 6



Fig. 7

Grand fir defoliated by tussock moth.  
Showing dead leader and adventitious shoots  
caused by previous defoliation.

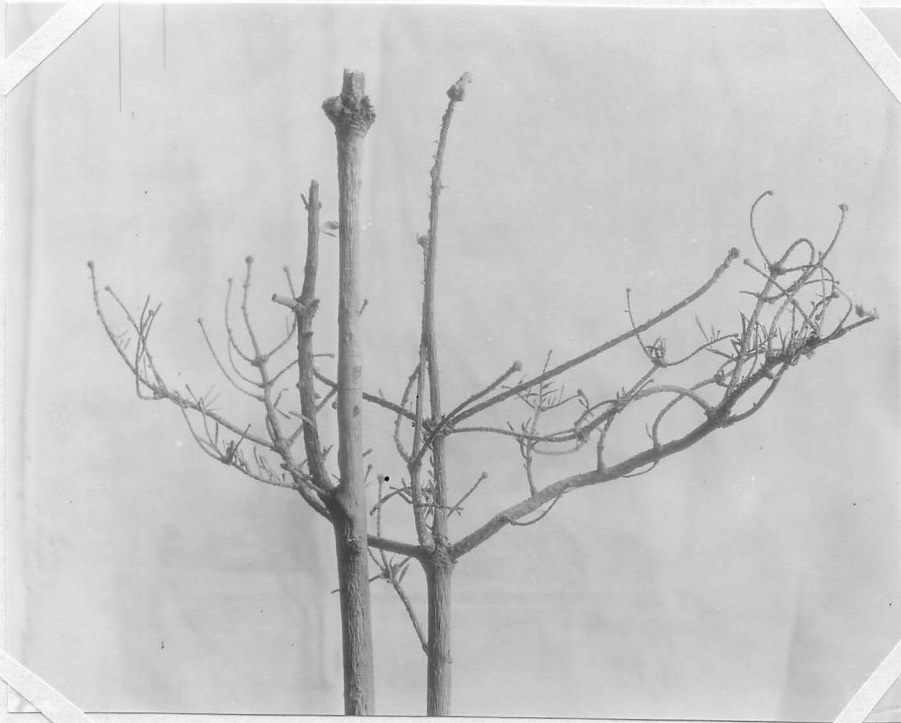


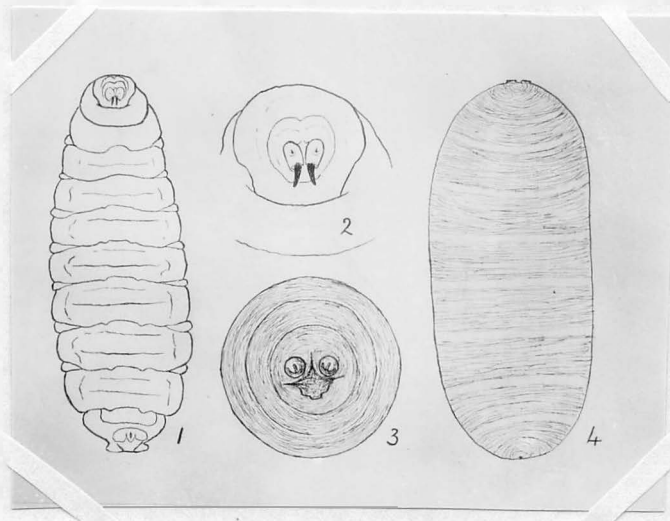
Fig. 8

Top of small grand fir defoliated by tussock moth. Crooks and dead leaders typical of reproduction in Weiser area. Probably due to previous attack by tussock moth or spruce budworm.



Fig. 9

Grand fir reproduction defoliated by tussock moth on the Weiser Forest.



Dipterous parasite important in control of tussock moth at Weiser.

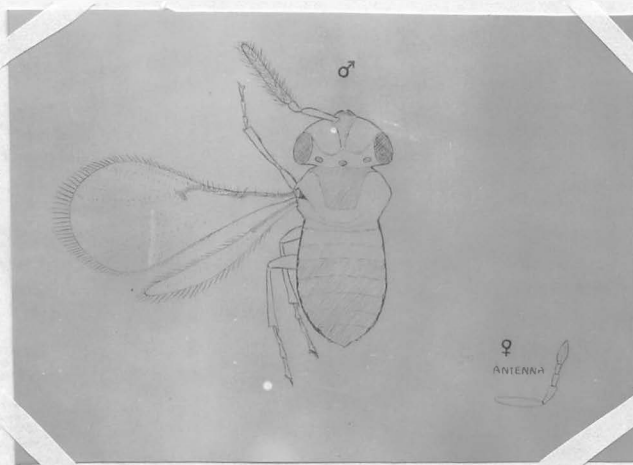
1. Mature larva
2. Head of larva
3. Posterior end of puparium
4. Puparium

Fig. 10



Dipterous and hymenopterous parasites. Parasitized prepupal larvae in cocoons.

Fig. 11



Trichogramma minuta Riley.  
Common egg parasite.  
X 50

Fig. 12

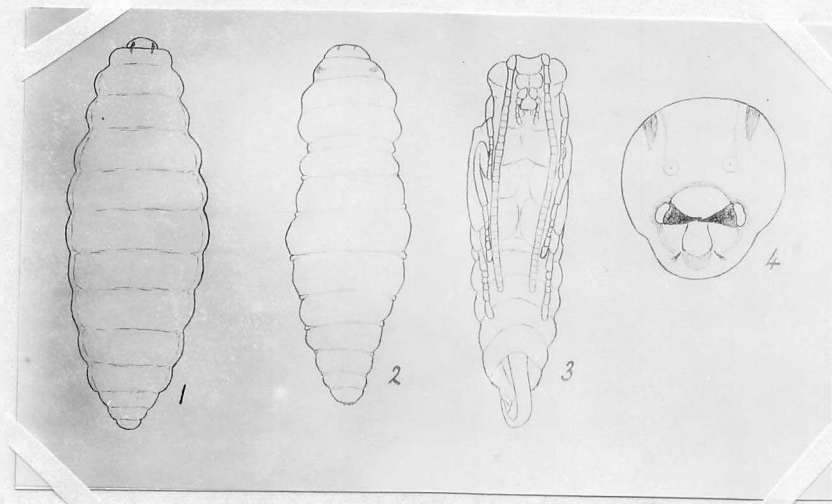


Fig. 13

Hymenopterous parasite Theronia fulvescens (Cress.)

1. Final instar larva -- dorsal view.
2. Early stage in transformation to pupa.
3. Pupa.
4. Head capsule of larva.

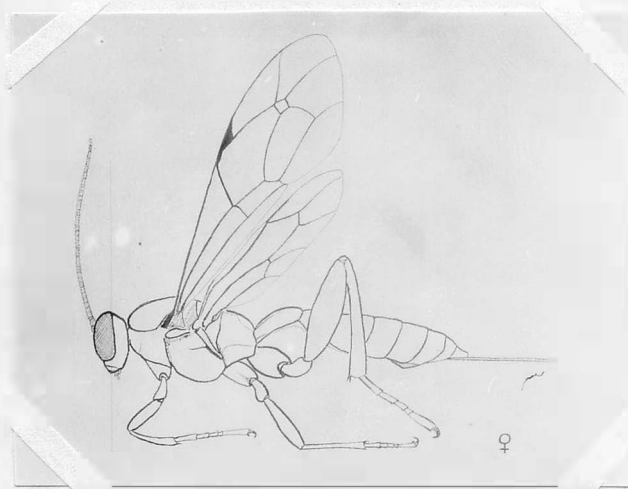


Fig. 14

Adult female of Theronia fulvescens (Cress.)